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A Method of Removing ISAR Image Stripe Noise Based on the Target Axis and the Energy Band Analysis

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Abstract

ISAR image after image forming are often mixed with various stripe noise to affect the image quality. In this paper, we propose a method based on the target axis and the target energy band analysis of ISAR, combined with curve fitting to remove the noise stripes of ISAR image. And the segmentation results of ISAR target with stripe noise removed show that the proposed method can effectively suppress Stripe Noise and protect the weak scattering points within the target area..

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Keywords: ISAR imaging; Stripe Noise; target axis; curve fitting; image segmentation

1. Introduction

There will appear Stripe Noise in the target image from ISAR image formation. It is mainly because of focusing badly and strong scattering point's secondary lobe and so on.

To suppress Stripe Noise, first, in the image processing phase compensation can be taken as accurately as possible to improve the focusing effect and reduce adverse focus; second, according to the characteristics of radar target image by pre-adoption after image formation, the noise stripes are suppressed. Figure 1 is ISAR image of a slurry machine in different postures.

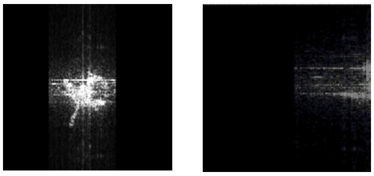

Figure 1 ISAR target images with Stripe Noise and coherent spot noise in different postures

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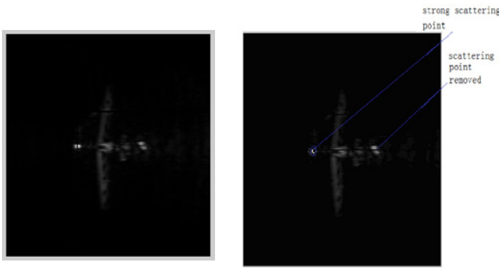
2. The Traditional Method of Fringes Noise Suppression

A simple method of removing stripe noise in image processing is that each unit is separately added to a threshold, for example, in each unit the points whose amplitude is less than one-tenth of the most amplitude are set to zero. Thus the stripe noise can be effectively inhibited in the strong scattering point unit, but the scattering points whose amplitude is weaker than the strong scattering points in the same unit may be accidentally deleted, resulting in the loss of their feature information.

Literature [5] points out: In theory, changes of stripe noise value always from the strong scattering points to both sides become smaller and smaller, so you can fit the curve formed by them with a quadratic function. The scattering points of ISAR image are sorted by descending, first the cure fitting is carried on for the lines and rows where the high strength scattering points are located, and then for the lines and rows where the lower strength scattering points, the curve fitting continues until the strength of the scattering points is below a certain value. After the curve fitting is complete and the value of each coordinate point minus the value of the fitting curve at that point, the stripe noise is off-set; at the same time the scattering points with smaller amplitude are preserved. Thus the purpose of removing interference is achieved, without causing the loss of feature information.

In practice, however, we found: 1. in the target area, the strong scattering points of the larger amplitude across the entire target area basically. The fringe curves fitted in accordance with the above approach completely cover the entire target area. The method is not a simple one removing stripe noise and it will lead a large number of weak scattering points without stripe noise to loss; 2. in accordance with the above approach, along the strongest scattering points the contrast before and after filtering is shown in Figure 2. If the target is in horizontal or vertical orientation, the major scattering points along the strongest scattering points' horizontal or vertical orientation besides the strongest scattering points will be removed.



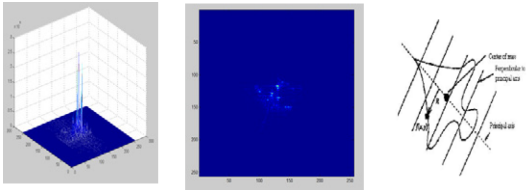
(a)ISAR target at the level of amplitude (b) the filtered image along the strongest scattering points

Figure 2 in accordance with the above approach along the strongest scattering point the image comparison before and after filtering

In response to the above problem, combined with the geometric moment invariants and determining of the target axis, we propose an improved method of removing stripe noise based on the curve fitting.

3. ISAR Target Axis Analysis

The literature[6,7,8] thinks that the distribution of the strong scattering points in the ISAR image is mainly near the target axis, we also proved it by experiment analysis, as shown in Figure 3 - (a) ,it can be seen that the strong scattering points of ISAR target distributes mainly along some axis



(a)Amplitude distribution (b) Energy distribution of ISAR image (c) Axis and energy band of the target of ISAR image

Figure 3 Amplitude of ISAR image and energy distribution

Figure 3 - (b) shows that the literature [6,7,8] proved along the vertical direction of ISAR target axis, a series of energy fringes exists indeed.

The direction of target axis, the target center, the energy fringes of the target and the major energy distribution are the main features of ISAR image processing. The relationship between them is shown in Figure 3 - (c). [6,7]

Target axis direction is defined as follows:

Suppose there are N points in ISAR image, $N*0.01$ points of the strongest strength are initially selected as the strong scattering points, set the coordinates of these points (x_i, y_i) , strength $f(x_i, y_i)$, $i = 0,1,\cdots, N*0.01$.

Calculate the covariance matrix of matrix A constituted by these points` coordinates [6, 7]

$$COVA=\begin{bmatrix} E(X_1-\mu_1)(X_1-\mu_1) & \cdots E(X_1-\mu_1)(X_n-\mu_n) \\ E(X_2-\mu_2)(X_1-\mu_1) & \cdots E(X_2-\mu_2)(X_n-\mu_n) \\ \vdots & \ddots \quad \vdots \\ E(X_n-\mu_n)(X_1-\mu_1) & \cdots E(X_n-\mu_n)(X_n-\mu_n) \end{bmatrix} \tag{1}$$

The eigenvector that the largest Eigen value of the covariance matrix corresponds with expresses the axis direction of the target.

3.1Target Center

Target center (x,y) can be obtained approximately by averaging the position of N * 0.01 points .

$$x_o = \frac{1}{N}\sum_{i=0}^{N-1} x_i \,, \quad y_o = \frac{1}{N}\sum_{i=0}^{N-1} y_i \tag{2}$$

3.2Target quantitative energy Band

The major axis is defined as the eigenvector that the largest eigenvalue λ of the covariance matrix corresponds with, the width of the band is proportional to λ , In the reported experiment, [7,8] selected coefficient $10e^{-5}$ as a constant ratio, so six bands can cover most of the target. In each band, the feature F is defined as:

$$F_j = \frac{\sum_{i=1}^{M_j} R_i^2 S_i}{\sum_{i=1}^{M_j} S_i} \qquad (3)$$

In the formula (3), M_j is the pixel number of band j , R_i is the distance between pixel i and the axis, S_i is the energy of the pixel. Here, the pixel gray value is directly used as energy.

3.3The main range of the target energy distribution

Calculating the length of the major axis and looking for the strong scattering points directly from the target center along the axis, the main range of the target distribution can be determined and so the main range of the target energy distribution can be calculated.[9]

In actual use, the main range of the target energy distribution can be calculated as follows:

1) Post-processing of imaging data, preliminarily determining strong scattering points;

2) for the range of the strong scattering point to carry on binarization, and to determine the foreground range, then recording the coordinates of the target points;

3) Constituting a matrix of the target coordinates;

4) Calculating the maximum feature vector and the size of the covariance matrix that the largest eigenvalue corresponds with;

5) Calculating the center and direction of the major axis, along the scope with the major axis vertical the major axis parted for 6 equal copies and computing the direction of the vice-axis and the intersection of the major and vice-axis;

6) Along the direction of the major axis, according to the vice-axis direction calculated to determine the quantitative calculation of energy fringes of these points.

4. Curve Fitting

Commonly to treat the cures the method used has two kinds: interpolation and fitting. Interpolation is that the data collected is as error-free state and to be handled. And in the ISAR image data processing, re-collecting data is impossible. If the approximate expression of the cure is demanded with interpolation, when a quite large amount of data, the interpolation not only causes a lot of trouble on the data calculations but high order interpolation may cause oscillation data.

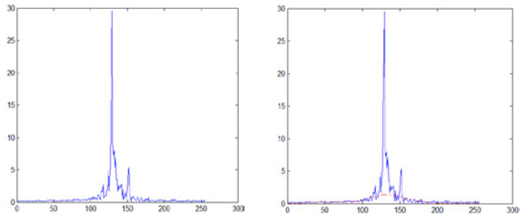
Therefore the curve fitting method should be used in the processing of ISAR image data. The curve fitting is a processing method of data which uses a continuous curve to approximately describe or compare functional relationship between coordinate represented by the discrete points on the plane, and the purpose is based on experimental data obtained to build the experiential functional relationship between dependent variable and independent variables. Generally, doing the best fitting with the least error square method of data points is a commonly used simple method.

4.1Fitting results

The stripes shown as Figure 1-(a) were fitted, Figure 4 - (a) is a drawing graphic with each point within the actual vertical stripes.

Figure 4 - (b) shows, in accordance with our approach and considering the existence of the energy stripes, the red curve is the fitting stripe curve drawn out. You can see the red curve has better maintained diffusion trend of the overall stripes noise from the strong scattering points outside, at the same time

avoiding the strong and weak scattering points weakening to excess. The curve fitting can be considered a success.



(a)the actual stripe (b) the curve after fitting

Figure 4 Fitting of ISAR target stripes

5. The Improvement Method of Removing Stripes Noise Based On The Curve Fitting

In the ISAR target data processing, the curve fitting of the ISAR data can be carried on separately by line and by row, and then removing the stripes noise. We have proposed an improved algorithm based on the above theory.

7) According to equation (1), carrying on an axis detection of the ISAR ($M \times N$), obtaining the target axis, the red curve shows in Figure 5;

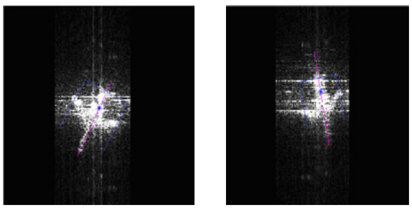


Figure 5 the axis and the energy distribution of ISAR target

8) The target center can be obtained from the equation (2), as shown in Figure 5, the blue "*" shows;

9) The target energy zone can be obtained according to equation (3), calculating the length of the major axis, drawing the main range of the target energy distribution, as shown in Figure 5, the blue box is the main area of the energy distribution;

10) Theoretically the noise stripes value changes always from strong scattering points toward two sides, gradually becomes small. we choose the orientation which follows the border place to the center to fit the curve, and along the border detect the starting point where the noise stripes are located. According to the experience the amplitude value of the points meeting the requirements should be larger than five thousandth of the amplitude value of the strongest scattering point. Generally the number of the starting points selected $n_m = M \times 0.2$ (crosswise) and $n_n = N \times 0.2$ (longitudinal);

11) Determining the noise stripes, according to the initial value point detected by the previous step

a) for the horizontal edge points, along the y-axis, finding the mean energy value of the all points outside the goal energy distribution range

b) for the vertical edge points along the x-axis, finding out the mean energy value of the all points outside the target energy distribution range.

c) in the horizontal edge taking the first few rows of the maximum mean value as the rows where the stripes are located, set the maximum mean value of each row is $Mean_{y_{\max}}$, the requirement mean value of the rows selected $Mean_{y_K} > 0.5 \times Mean_{y_{\max}}$.

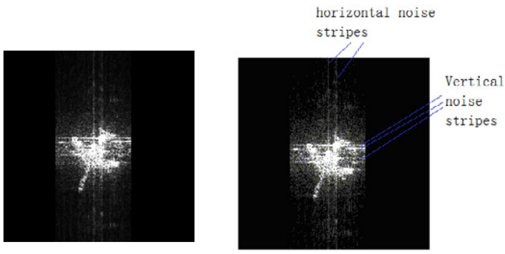
d) in the vertical edge taking the first few lines of the maximum mean value as the lines where the stripes are located, set the maximum mean value of each line is $Mean_{x_{\max}}$, requiring the mean value of the lines selected $Mean_{xL} > 0.5 \times Mean_{x_{\max}}$.

12) Carrying on the fitting to the data selected:Although the points selected are outside the target energy stripes, theoretically change of the noise stripes value always decreases gradually from the strong scattering points to both sides, so the curves after fitting can be used to predict change trend of the stripes points within the range of the target energy stripes;

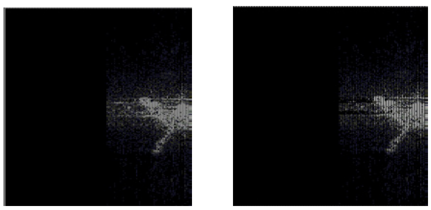
13) According to the curve fitting results of each point in the stripes the stripes noise are removed directly.

6. The Experimental Result of Removing Stripe Noise

We have carried on stripe identification of 500 images of five kinds of ISAR targets, only in 7 images appears false identification of individual stripe (in one image 8 stripes identified as 9, in six images separately missing identification 1), and the correct rate reaches 98.6%. Figure 6 shows the result of ISAR stripes removal in Figure1-(a).



(a) Original image (b) Stripes detected



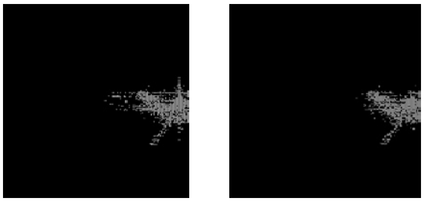
(c) The image of the longitudinal stripes removed (d) the image of all stripes removed

Figure 6 Noise stripes removal

For Figure 6 - (d), the experimental data show that in the removal of the longitudinal stripes, the points with residual value less than 20% have relation with the proportion occupied by the ISAR target in the ISAR image, at the same time data analysis proves the points with residual value more than 20% are basically located within the target energy stripes, so the weak scattering points are better protected; in the removal of the horizontal stripes, as Figure 1 - (a) shown, ISAR target in the horizontal orientation occupies more than half of the effective image area , and because of the presence of energy stripes, the points of residual value more than 20% are more, which is consistent with the actual situation. Although there are less data in the area available for fitting and in the individual position appear weaker residues, it may not affect the overall result.

7. Conclusion

Figure 7 shows the comparison of ISAR image segmentation results before removing noise stripes and after, you can see the method in the paper has effectively removed the influence upon ISAR image for stripes noise, and has laid down a good foundation for further segmentation of ISAR image and extraction of the target feature.



(a) ISAR image segmentation results before stripes noise removed

(b) ISAR image segmentation results after stripes noise removed

Figure 7 the comparison of ISAR image segmentation results before removing stripes noise and after

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